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Cooperation and Endogenous Repetition

in an Infinitely Repeated Social Dilemma

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Abstract:

A large body of theoretical and experimental literature suggests that exogenously imposed infinite repetition can mitigate people's opportunistic behavior in dilemma situations through personal enforcement. But, do people collectively choose to interact with the same persons, when there is an alternative with random matching? In a framework of an indefinitely-repeated collective action dilemma game, we let subjects collectively choose whether to (i) play with specific others for all rounds or to (ii) play with randomly matched counterparts in every period. The experiment showed that most subjects collectively select the partner matching option. It also indicated that groups achieve a higher level of cooperation when subjects collectively select option (i) by voting, compared with when the same option is exogenously imposed. These findings have an implication that people's equilibrium selection may be affected by how the basic rules of games are introduced (endogenously or exogenously) to them.

JEL classification: C92, H41, C73, D72

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1. Introduction

Collective action dilemmas, where free riding is a strictly dominant strategy but mutual contributions leads to a Pareto optimum, are ubiquitous in our real world. A rich body of theoretical and experimental studies has put considerable efforts into exploring how to overcome people's opportunistic behavior in such dilemma situations. One of the most established behavioral findings in recent decades is that people contribute to public goods to some degree even in one-shot games or in earlier rounds of repeated dilemma games (e.g., Ledyard 1995, Chaudhuri 2011). However, it has also been shown that people cannot cooperate with each other to a high degree without an institution that facilitates their cooperation, such as peer-to-peer monetary or non-monetary punishment opportunities (e.g., Fehr and Gächter 2000, Masclet, Noussair, Tucker and Villeval 2008), because of serious tensions between cooperation and non-cooperation in dilemma situations.

One important finding from research on dilemmas is that people's decision to cooperate can be significantly altered if the games involve infinite repetition (the possibility to repeatedly interact with the same players until an unknown time period). Theoretically, mutual cooperation, in addition to mutual defection, holds as an equilibrium outcome with partner matching through personal enforcement if the agent is sufficiently patient. Experimental tests for the theory of infinitely-repeated games can be conducted using indefinitely-repeated setups with a random continuation rule (Roth and Murnighan 1978). The evolution of cooperation has been often tested by using prisoner's dilemma games in the past studies. The experimental literature shows that when the partner matching is used, indefinite repetition indeed encourages people to behave more cooperatively under some conditions, compared with the environments where players know the precise length of the repeated games in which case mutual defection is the unique equilibrium (e.g., Roth and Murnighan 1978, Murnighan and Roth 1983, Feinberg and Husted 1993, Dal Bó, 2005, Duffy and Ochs 2009, Dal Bó and Fréchette 2011).[2] However, not everyone chooses to cooperate in many cases even with indefinite repetition. For instance, in Dal Bó (2005), the average cooperation rates range from 20% to 50% in almost all treatments even when prisoner's dilemma games are indefinitely repeated. In Dal Bó and Fréchette (2011), cooperation

[2] See Dal Bó and Fréchette (forthcoming) for a survey of the literature. There are also some other experiments that showed that indefinite repetition did not increase the level of cooperation, compared with finite-repeated environments (e.g., Lugovskyy *et al.* 2015).

does not evolve even with experiences if mutual cooperation situation is only sub-game perfect but a cooperative action is not risk-dominant. Dal Bó and Fréchette (2011) further show that cooperation does not always evolve, even if cooperation is an equilibrium action and it is also a risk-dominant action.

Even when we assume that people interact with different players from round to round, it is theoretically shown that, with infinite repetition, community enforcement can sustain cooperation under some conditions (e.g., Kandori 1992, Ellison 1994). Recent experimental literature in this area also shows that indefinite repetition may encourage people to cooperate even if no information regarding their interaction partners' past action choices is available. However, experimental results with random matching are rather mixed and not established: while some studies found positive impact of indefinite repetition even when subjects are not provided any information on randomly-matched partners (e.g., Camera and Casari 2009), other studies found no impact (e.g., Duffy and Ochs 2009, the N treatment in Kamei forthcoming b).[3]

One possible channel that may boost cooperation with partner matching is a democratic decision-making process where players themselves *collectively* select the matching protocol. But do people collectively choose to play with the same players, when there is an alternative with random matching? How does such collective decision-making affect people's cooperation behavior (equilibrium selection) if people implement the partner matching? As discussed earlier, the past studies have shown that not everyone chooses to cooperate with specific others even with indefinite repetition. These two equally-important research questions have not been studied in the literature.

Examples where people collectively decide whether to play with each other indefinitely are abundant in our real life, especially for small-group interactions. Imagine, for example, charitable or voluntary groups that are formed to help the poor in a community. They sometimes collectively decide to work together for an indefinite amount of time, instead of meeting randomly and creating groups that consist of different members each time. Other examples include student groups that act for purposes such as environment protection, sports and political

[3] There are also conflicting results from past studies for the impact of indefinite repetition on the evolution of cooperation when some information on interaction partners is disclosed. While Camera and Casari (2009), Stahl (2013) and Kamei (forthcoming b) found that cooperation evolved with reputational information, Duffy and Ochs (2009) found that it did not.

activities. Do people prefer to work with specific peers, instead of engaging in activities where they meet their peers randomly and form groups? Does such a collectively-made decision to interact with each other for an indefinite length of time affect people's level of cooperation in dilemma situations? For another example, consider international organizations, such as the United Nation. These organizations are formed by countries that share the vision of the organizations (e.g., poverty alleviation) and the member countries carry out missions together to achieve the common goals. The member countries do not usually change very often. The alternative would be for countries with common concerns to reach out each other and act together to combat an issue. The partner countries may or may not be the same every time a country engages in such a project.

This paper experimentally studies people's collective choice between two different matching protocols under the shadow of the future and the impact of the democratic decision-making on their cooperation behavior with partner matching in a framework of a linear public goods game (also known as voluntary contribution mechanism). In groups of four, each subject is given a fixed endowment and decides simultaneously how much to contribute to their group in every period. We design two treatments: one for the control condition and the other for the treatment condition. The two treatments are identical, except for the implementation process of the matching protocols between subjects. In the control condition, subjects play the public good game indefinitely with three fixed individuals without any agreement procedures. By contrast, in the treatment condition, subjects are randomly assigned to groups with three individuals at the onset, and then each group collectively decides whether they want to play the public goods game with each other (i) for all rounds subject to a random continuation or (ii) for one round only. The collective decisions are made by unanimity rule. Subjects repeat voting until they reach an agreement. Agreement procedures in small-group interactions mentioned in the above examples often take a form of unanimity rule. Unanimity rule is also employed, for example, not only by international organizations, such as the United Nation, but also by political unions, such as the European Union. Some past experimental studies have modeled democratic decision-making processes by using unanimity rule, including Sutter, Haigner and Kocher (2010). (As will be explained in Section 5, we also conducted an additional treatment with majority rule as the democratic decision-making procedure for a robustness check because majority rule is another widely used form of democratic decision-making.)   Option (i) is a standard partner matching regime. By contrast, option (ii) is a standard random matching regime. That is, if a group selects option (ii), the group is dissolved after the one-time interaction. In the following round, subjects will be randomly re-matched with three individuals from groups that selected option (ii), and play the one-shot public goods game. This process – dissolution, random matching and one-shot public goods game – continues with a fixed probability (the random continuation rule). Experimental parameters are set so that (a) contributing nothing for the group is a strictly dominant strategy if the stage game is played just once but (b) if the stage game is infinitely repeated it becomes a coordination game where any symmetric, positive contribution situation is one of the equilibria, regardless of which option (i) or (ii) a group selects. While the mechanism with which symmetric, positive-contribution equilibria hold is the personal enforcement under option (i), it is the community enforcement under option (ii). In order to perform additional analyses as to how subjects' beliefs are affected by the presence of the voting procedure, we elicit subjects' beliefs on their interaction peers' average contribution in the indefinitely-repeated game just before moving on to the sequence of allocation stages in each treatment.

A theoretical analysis suggests that the subjects' average contribution amounts would be higher with option (i) than with option (ii), because the threshold continuation probability that makes any symmetric positive-contribution situations materially beneficial, relative to free riding on their peers' cooperation, is lower with option (i) than with option (ii). As for subjects' collective choices, past research suggests that subjects may be more likely to vote for option (i), rather than option (ii), because of four particular reasons. First, collectively selecting to play with specific others may serve as a signal that members will cooperate with other group members in the supergame (e.g., Tyran and Feld 2006). Second, voting in favor of playing together in a given infinitely-repeated game may also serve as an opportunity to indirectly persuade those who initially did not plan to cooperate, as is similar to the logic of persuasion through cheap talk, or coordination via pre-play communication in coordination games (e.g., Cooper, DeJong, Forsythe and Ross 1992, Blume and Ortmann 2007). Third, according to recent literature on sacrifice, some people prefer to reduce their temptation to free ride when given a chance to do so (e.g., Aimone, Iannaccone and Makowsky 2013, Grimm and Mengel 2009). In our setup, the temptation to free ride is higher with option (ii) than with option (i) because the "hit-and-run" strategy (i.e., defect and then escape from the current group members) is possible with the random-matching option. Fourth, the democratic decision-making process itself (excluding any instrumental effects it may have, such as selection bias and the effects of information) may also help enhance cooperation (e.g., Dal Bó, Forster and Putterman 2010, Kamei 2016a, Sutter, Haigner, Kocher 2010, Tyran and Feld 2006). The so-called "democracy premium" may make option (i) more attractive to subjects.

Our experiment reveals that, first, almost all groups choose to interact with three pre-assigned individuals for all rounds in the treatment condition. Second, subjects contribute significantly more in this condition, compared with subjects in the control condition where the same rule is exogenously assigned to them. A detailed analysis suggests that the difference in the subjects' contribution behavior between the treatment and control conditions is not due to selection effects (e.g., Tyran and Feld 2006, Dal Bó, Forster and Putterman 2010, Dal Bó, Forster and Kamei 2015) but can be explained by higher beliefs formed by subjects in the treatment condition, as in the signaling hypothesis (e.g., Tyran and Feld 2006). This implies that democratic decision-making may significantly affect subjects' equilibrium selection in an infinitely-repeated collective action dilemma by influencing their beliefs.

In order to check the robustness of the findings summarized above, we also conducted an additional treatment by changing the unanimity rule to majority rule, while keeping all of the other design pieces of the original endogenous treatment the same. The additional data with majority voting replicates qualitatively almost the same results as in the original treatments. This implies that our results may not depend on which voting rules are used in democratic decision-making.

The rest of the paper proceeds as follows: Section 2 describes our experimental design. Section 3 briefly provides theoretical considerations. Section 4 reports results, and Section 5 summarizes results from the additional treatment. Section 6 concludes.

2. Experimental Design

The design frame of our study is an indefinitely-repeated public goods game. Group size is four. We let subjects play the indefinitely-repeated game five times in both of the two treatments.[4] The repeated supergame design was chosen, instead of a one-shot supergame design, in order to explore how people's collective choices change from supergame to supergame and

[4] The term "phase" was used in the experiment to refer to indefinitely-repeated game.

how the impact of democratic decision-making persists over time. We employ a standard stranger matching protocol for matching across the supergames. That is, at the onset of each supergame, group compositions are randomly changed. The duration of each supergame is stochastically determined. We set the random continuation probability as 75%: subjects in the t^{th} round of a given supergame will have the next round (i.e., round $t + 1$) with a probability of 75% (the supergame ends with a probability of 25%). Therefore, the expected length of subjects' interactions is 4 (= 1/(1 – .75)) rounds in each supergame. This feature of stochastic determination of the game duration is common knowledge in the experiment.

The experiment consists of an endogenous treatment and an exogenous treatment (Table 1). We adopt a between-subjects design. The reason that we employ the between-subjects design, instead of a within-subjects design, is that democratic decision-making may affect subjects' behavior beyond the environment where subjects make decisions. This indirect effect of democratic decision-making is defined as the spill-over effect of democracy in Kamei (2016a). In other words, we would obtain cleaner data if we divide subjects into the treatment groups and the control groups and then let them play the game under only one condition than otherwise.

This paper's empirical strategies to identify the impact of democratic decision-making are as follows:

Strategy *a*: *to compare subjects' action choices in the 1st supergame between the two treatments but use the rounds that occurred in all sessions of the 1st supergame.*

Strategy *b*: *to compare subjects' action choices in all supergames between the two treatments but use the rounds that occurred in all sessions*.

The strategies to compare subjects' behaviors in the same number of rounds between the two treatments is employed because each supergame likely has different length by session due to the random continuation rule and would not be comparable between sessions (and accordingly between the two treatments) if we use every data. With strategies *a* and *b*, we most likely use the first round of each supergame to study the democracy effects. Because we use the continuation probability of 75%, the probability that at least two rounds occur in all sessions of both of the two treatments is: $(.75)^K \times 100[\%]$, where K is the number of sessions. As will be explained in Section 4, there are three sessions per treatment. Thus, $K = 6$. In other words, the probability that at least two rounds are realized in all the six sessions is very low – only 17.8% (= $(.75)^6 \times 100$).

We perform analyses using strategy *a*, in addition to using strategy *b*, because data in the first supergame is cleaner than that of the 2nd to 5th supergames because subjects' experiences in the first supergame would differ by session due to the random continuation rule. The difference in subjects' experience in earlier supergames may affect their contribution and voting behavior in the later supergames. We now explain each design piece one by one.

2.1. The Stage Game

The stage game used in the two treatments is a public goods game. In every round, each subject is given an endowment of 20 points, and they simultaneously decide how much to allocate to their private and public accounts. The contribution amount must be an integer between 0 and 20. The sum of allocations to the private account and the public account must be 20 points. The payoff consequence follows the standard linear public goods game. That is, for each point that a subject allocates to her private account, she obtains one point as her payoff without affecting the payoffs of her group members. For each point she allocates to her public account, she and her three partners each obtain Marginal Per Capita Return (MPCR) = .4 points as payoffs. In summary, when subject i contributes $C_{i,t}$ to the public account in round t, she obtains the following payoff:

$$20 - C_{i,t} + r\sum_{j=1}^{N} C_{j,t}, \tag{1}$$

where $r = .4$ and $N = 4$ in this study. Note that $1/N < r < 1$.

2.2. The Treatment Condition

In the endogenous treatment, which we call the "ENDO" treatment, after subjects are randomly assigned to a group of four in each supergame, they collectively decide the duration of interactions by voting for that supergame. The voting option is either "all rounds in a given supergame" ("all rounds", hereafter) or "one round."[5] We can interpret this collective choice as a choice between continuation probabilities of .75 and .00. The collective decision is made by unanimity rule. In this collective-decision stage, four members of a group continue to vote until all votes for the same option. The maximum number of the voting stages is 20.[6] In case where

[5] The two options were called "all periods in a given phase" and "one period" in the experiment.
[6] The maximum number of voting stages is set in order to avoid the duration of the experiment being too long.

four members do not agree on one option in the 20th voting stage, majority rule is applied to determine the group's choice.[7]

If a group selects the "all rounds" option, then the four subjects interact with each other until the end of a given supergame. By contrast, if the group selects the "one round" option, their interaction is one-shot. Groups that selected the option of "one round" are dissolved after the one-shot interaction. They are then randomly assigned to new groups of four among them and play the game with the three new peers once. The process of dissolution, re-matching and one-shot public goods game repeats with a continuation probability of 75%.[8]

2.3. The Control Condition

In the exogenous treatment, which we call the "EXO" treatment, there is no opportunity for subjects to collectively decide the duration of interactions. Instead, subjects are instructed that they will play with three pre-assigned members for the entire rounds in a given supergame.[9]

2.4. Elicitation of Beliefs

We elicit subjects' beliefs in order to examine what influences their decisions to contribute as an additional analysis. Specifically, in the ENDO treatment, after the voting stage and before moving on to the sequence of allocation stages, regardless of vote outcomes, subjects are asked about beliefs on the average contribution amount to the public account by their interaction peers during a given supergame. Likewise, subjects in the EXO treatment are also asked to state their beliefs on their interaction peers' average contribution amount at the onset of each supergame.

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[7] When votes are split equally between the two options in the 20th vote, one of them is randomly (i.e., with a probability of 50%) selected by the computer.

[8] If the number of groups that chose the option of "one round" is only one, then the group members interact with each other for all rounds in the given supergame because there are no other groups to be dissolved. Subjects are not informed how many groups selected the "one round" option.

[9] We acknowledge that there are other ways to design the control treatment. For instance, another possible way to design the control treatment would be to assign each option stochastically to control groups with the actual percentages of groups which select each option in the ENDO treatment, without informing subjects of the percentages of stochastic implementation. We did not employ this method because subjects in the ENDO treatment were able to guess the likelihood of implementation of an option to some degree as subjects' votes determine collective choices. Alternatively, we could stochastically impose one of the two options on control groups while notifying subjects the percentages of stochastic determination. However, this control treatment design is not perfect either as subjects in the ENDO treatment are not given the information on how many groups select the "all rounds" or "one round" option.

We note that the belief elicitation task is not incentivized in order to minimize its effects on subjects' action choices because this paper's focus is on subjects' voting and their actual contribution behaviors.[10] Possible effects of incentivized belief elicitation have been documented (see, for example, Gächter and Renner 2010 for the detail).[11]

3. Theoretical Considerations and Discussions

The standard theory does not provide a point prediction in our setting. In the EXO treatment, not only the mutual free-riding but also any symmetric, positive contribution situation holds as an equilibrium outcome since we adopt 0.75 as a continuation probability. To illustrate a possibility of the mutual full contribution equilibrium in this control treatment, suppose that all four individuals in a group have contributed their full endowment amounts (E) to the public account before round t and have been and will be following a grim trigger strategy. That is, a subject i contributes E points until she sees at least one instance of defection where one of the individuals in her group contributes less than E; once i faces the defection she starts contributing 0 points until the end of a given supergame. In this situation, if subject i continues to follow the grim trigger strategy in and after round t, her expected payoff ($E[\pi_i]$) is calculated as:

$$E_t[\pi_i]^{cooperate} = \sum_{s=t}^{\infty} \delta^{s-t} \cdot \pi_{i,s}(c_{i,s}) = \frac{r \cdot N \cdot E}{1-\delta} = 128, \tag{2}$$

where E = 20, r is the *MPCR* (= .4), N is group size (= 4) and δ is the continuation probability (= .75). Alternatively, if she changes her strategy and contributes 0 points in round t, her expected payoff is maximized by also contributing 0 points in any rounds after round t because the other three players will not cooperate as they are following the grim trigger strategy. The maximum payoff is thus calculated as:

$$E_t[\pi_i]^{defect} = E - 0 + r \cdot (N-1) \cdot E + \sum_{s=t+1}^{\infty} \delta^{s-t} \cdot \pi_{i,s}\left(c_{i,s}\right) = 44 + \frac{\delta \cdot E}{1-\delta} = 104, \tag{3}$$

[10] See Sections (c) and (d) in Appendix A for computer screen images for this elicitation task.

[11] Gächter and Renner (2010) let subjects play ten-period finitely-repeated linear public goods game with the same experimental parameters as this paper (the per-subject endowment is 20 points and the MPCR (r) is .4). Their results indicated that elicited beliefs were more accurate when they were incentivized than when they were not incentivized (although the mean difference was only 0.59 points), but the incentivized elicitation significantly affected subjects' contribution amounts. If subjects' beliefs were not incentivized, by contrast, their contribution amounts were not significantly different from those in a treatment where beliefs were not elicited. Gächter and Renner (2010) suggest that "If the researcher is afraid that belief elicitation leads to behavioral results that he or she would not obtain when not asking for beliefs, then […] belief elicitation should not be incentivized" (page 372).

which is less than the mutual full contribution payoff in Eq. (2). It is therefore not materially beneficial for *i* to deviate from the mutual full contribution situation. Note that the threshold value of δ so that the mutual full contribution situation can be supported as an equilibrium outcome is 0.5, which is much less than .75.

There also exist a symmetric, positive, but less-than-full-contribution equilibrium for any contribution level $\xi \in \{1, 2, \ldots, E\}$ in the EXO treatment. The existence of such equilibria can be checked with the same logic that assumes the subjects' grim trigger strategy. With the symmetric contribution equilibrium with the contribution level of ξ points, subject *i* obtains a payoff as in Eq. (4):

$$E_t[\pi_i]^{continue\ to\ contribute\ \xi\ \text{points}} = \sum_{s=t}^{\infty} \delta^{s-t} \cdot \pi_{i,s}(\xi) = \frac{E-\xi+r\cdot N\cdot\xi}{1-\delta}. \tag{4}$$

If subject *i*, by contrast, contributes 0 points to the public account in a given period, she obtains the following as maximum payoff:

$$E_t[\pi_i]^{defect} = E - 0 + r\cdot(N-1)\cdot\xi + \sum_{s=t+1}^{\infty} \delta^{s-t}\cdot\pi_{i,s}(0)$$

$$= E + r\cdot(N-1)\xi + \frac{\delta E}{1-\delta}. \tag{5}$$

Eqs. (4) and (5) suggest that $E_t[\pi_i]^{continue\ to\ contribute\ \xi\ \text{points}} > E_t[\pi_i]^{defect}$, regardless of the value of ξ, if δ is greater than 0.5. We also see that Eq. (4) is monotonically increasing in the mutual contribution level ξ. In other words, the strategic situation that subjects face is the one with Pareto-ranked multiple equilibria.

The same holds true also for groups that select the "all rounds" option in the ENDO treatment. These groups face the same strategic situation with Pareto-ranked multiple equilibria.

OBSERVATION 1: *Not only the mutual full free-riding situation, but also any symmetric, positive contribution situation holds as an equilibrium outcome in the EXO treatment. The subjects in groups where the "all rounds" option is collectively implemented in the ENDO treatment face the same strategic situation as subjects in the EXO treatment.*

Subjects have stronger incentives to defect in groups where the "one round" option is implemented because they can hit and run considering that the groups will be dissolved after a given round and they may be matched with subjects from other groups in the following rounds.

However, one instance of defection spreads very quickly to other subjects in groups with the "one round" option, as in the logic of Kandori (1992), if we assume that each subject employs a grim trigger strategy. Because of this contagion process, a symmetric, positive contribution situation with any level $\xi \in \{1, 2, \ldots, E\}$, including the mutual full contribution situation, holds as an equilibrium outcome. Incentives to defect depend on how many groups select the "one round" option. For an extreme example, suppose that there are 24 subjects in the experiment and all of the groups (six groups) selected the "one round" option. As will be explained later, the number of groups per session was either five or six in the experiment. Because the incentive to defect is largest in this extreme situation, if symmetric positive contribution situations are supported as an equilibrium outcome in this situation, there is also no incentive for subject *i* to deviate from the grim trigger strategy when the number of groups that selected the "one round" option is less than six. As calculated in Appendix B, even in this extreme situation, when subject *i* contributes less than ξ points in round *t*, the percentages of full free-riders out of the other 23 subjects becomes around 90% by round $t + 3$ even if the 23 subjects have contributed ξ points until round *t*. Due to the rapid contagion of free-riding, the total expected payoff from the defection is lower than the mutual cooperation payoff, which is $(E - \xi + r \cdot N \cdot \xi)/(1 - \delta)$. This means that there is no incentive for *i* to deviate and thus any symmetric contribution situation holds as an equilibrium outcome. These considerations are summarized as in the following observation:

OBSERVATION 2: *Regardless of how many groups select the "one round" option, both mutual full free-riding situation and any symmetric, positive contribution situation (including the mutual full contribution situation) hold as equilibria when the "one round" option is collectively implemented in a given supergame.*

Despite Observations 1 and 2, a symmetric contribution equilibrium for a given contribution level (ξ points) would be more easily attained when the "all rounds" option is collectively selected. This is because the threshold value of continuation probabilities with the "one round" option that support mutual contribution as an equilibrium outcome ($\bar{\delta}^{one\ round}$) is higher than or equal to that with the "all rounds" option ($\bar{\delta}^{all\ rounds} = .5$). As discussed, group composition changes in every period among those who selected the "one round" option. $\bar{\delta}^{one\ round}$ would coincide with $\bar{\delta}^{all\ rounds}$ if only one group selects the "one round" option and the members of this specific group is aware of the fact that they are the only group that selected the "one round" option, which is less likely to be the case; but the former is always larger than the latter in any other situations. This means that subjects' incentives to deviate are smaller when the "all rounds" option is selected than when the "one round" option is selected. We can therefore summarize the difference in subjects' contribution behavior as in OBSERVATION 3:

OBSERVATION 3: *Any given symmetric contribution situation is more easily attained when the "all rounds" option is collectively selected than when the "one round" option is selected.*

OBSERVATION 3 suggests that the average contribution in groups that select the "all rounds" option would be higher than that in groups that select the "one round" option. This leads to the following first specific hypothesis in our study.

HYPOTHESIS 1: *Groups who select the "all rounds" option make a significantly higher level of contributions than groups who select the "one round" option.*

Then, which option do groups collectively select? There are two factors in particular that may encourage subjects to vote for the "all rounds" option in our context. First, a subject's vote in favor of the "all rounds" option can serve as a signal that she intends to contribute large amounts in a given supergame because of Hypothesis 1 (e.g., Tyran and Feld 2006). Past experimental studies have demonstrated the significant impact that a coordination device has on equilibrium selection in coordination games (e.g., Cooper, DeJong, Forsythe and Ross 1992, Blume and Ortmann 2007). For instance, Cooper, DeJong, Forsythe and Ross (1992) shows that in a one-shot two-person coordination game where one equilibrium is Pareto optimal, two-way pre-play communication (in that subjects can send a message as to which action they choose) helps subjects choose the Pareto-dominant Nash Equilibrium. As the two-way signaling channel facilitated by the democratic decision process can act as a coordination device, subjects in the ENDO treatment may believe that others would contribute significantly higher amounts if the "all rounds" option is collectively selected, compared with subjects in the EXO treatment.[12] Second, voting for the "all rounds" option means that the subject prefers to sacrifice the high temptation to deviate under the "one round" option. Recent experimental research suggests that

[12] The importance of beliefs when subjects choose actions has also been proposed and experimentally demonstrated in finitely-repeated setups (e.g., Kreps, Milgrom, Roberts and Wilson 1982, Selten and Stoecker 1986, Andreoni and Miller 1993, Kamei and Putterman 2017, Kamei 2016b).

some subjects prefer to reduce temptation to defect given an opportunity to do so in dilemma situations. For instance, Aimone, Iannaccone and Makowsky (2013) give subjects an opportunity to reduce returns from private account in a public goods game on condition that (a) mutual free-riding remains to be the unique Nash equilibrium of the material payoff and (b) those who select a similar level of sacrifice for private returns are matched with each other by a sorting mechanism. Their study found that around half of subjects prefer to reduce the temptation to free ride and cooperate with like-minded others at a high level although the amount of temptation to reduce differs by subject.[13] In our study, not only mutual full free-riding but also any symmetric contribution situation holds as an equilibrium outcome under both of the two options (Observations 1 and 2). Although subjects in our study also do not have self-sorting opportunities, the findings of research such as Aimone, Iannaccone and Makowsky (2013) may extend to our setups where there are multiple Pareto-ranked equilibria. These past experimental studies lead to the following specific hypothesis in our study:

HYPOTHESIS 2: *Most groups select the "all rounds" option in the ENDO treatment.*

Subjects' contribution behavior under the "all rounds" option may differ between the ENDO and EXO treatments. First, as already discussed, democratic decision-making provides an opportunity for subjects to send signals of their future contribution behavior (e.g. Tyran and Feld 2006). For instance, Tyran and Feld (2006), using a one-shot linear public goods game with group size of three and a non-deterrent sanction law, showed that the more supporters of the non-deterrent sanction there are in a group, the higher amounts subjects contribute to the public good.[14] Further, they found that subjects' contribution amounts and their expectations of peers' contribution amounts are positively correlated when the non-deterrent sanction law has been imposed. Second, there may also exist the democracy premium – which is a residual effect of the democratic decision process seen even after controlling for selection bias and the effects of information through voting. In other words, the democracy premium is the effect that democratic decision-making directly has on people's behavior (Dal Bó, Foster and Putterman 2010, Kamei 2016a, Markussen, Putterman and Tyran 2014, Sutter, Haigner, Kocher 2010, Tyran and Feld

[13] See Grimm and Mengel (2009) and Frédéric and Weber (2013) also.

[14] Tyran and Feld (2006) used a strategy method in that each subject was asked to indicate how many points to contribute to the public good on condition that the numbers of supporters are 0, 1, and 2.

2006).[15] Subjects may have a higher willingness to cooperate due to the democracy premium, compared with subjects in the EXO treatment.

HYPOTHESIS 3: *(a) Subjects who select the "all rounds" option in the ENDO treatment contribute significantly larger amounts than subjects in the EXO treatment. (b) Beliefs formed by subjects who select the "all rounds" option in the ENDO treatment are significantly higher than those in the EXO treatment, as is consistent with the signaling hypothesis. (c) There is some positive effect from democratic decision-making on enhancing cooperation even after controlling for the difference in subjects' beliefs between the two treatments.*

Hypothesis 3(a) is related to one of the main questions of this paper, whereas Hypotheses 3(b) and (c) explain what may drive Hypothesis 3(a). Hypotheses 3(b) and (c) can be studied using the beliefs elicited from subjects in the experiment.

4. Results

The experimental sessions were conducted at the Centre for Experimental Economics (EXEC) laboratory at the University of York in the United Kingdom from October to December 2015. All subjects were students at the University of York. In total, six sessions – three for each treatment, were conducted. Each session consisted of five or six groups. Subjects voluntarily registered for and participated in the experiment. They were recruited by solicitation messages sent through HRoot (Bock, Nicklisch, and Baetge 2014). No subject participated in more than one session. Client computers were separated from each other by three sufficiently tall partitions (one for the front and two for the sides). No communication was permitted throughout the entire experiment.

All experimental procedures except the instructions and comprehension questions were computerized. They were programmed in ztree (Fischbacher 2007). All instructions were neutrally framed (see Appendix A). Any words with positive or negative connotation (e.g., contribute, public goods) were avoided. At the onset of the experiment, the instructions were handed out to subjects and were read aloud by the experimenter. Then, subjects were asked to

[15] We note that the presence of the democracy premium may depend on the distribution of income. All of the papers cited here used experimental setups where endowments were the same among subjects. By contrast, the democracy premium was not observed in Kamei (forthcoming a), where subjects collectively selected a public goods game or a lottery contest when endowments were unequally distributed among the subjects.

answer comprehension questions to check their understanding of the experiment. At the end of the experiment, each subject was privately paid based on their interaction outcomes. The average per-subject payoff (including £3 for participation fee) was 14.70 pounds sterling.

4.1. Subjects' Voting Behavior

We first look at subjects' vote outcomes to address our first research question (people's collective choice). First, as consistent with Hypothesis 2, our experiment shows that most groups collectively prefer having the "all rounds" option in the ENDO treatment from the first supergame (Table 1). Specifically, 15 out of 16 groups chose to play with the same players for all rounds in the first supergame. The percentages of groups that chose this option stayed similar during the five supergames, except the 3rd supergame where the percentage was slightly lower.

Second, although we found the overwhelming support for the "all rounds" option, the number of voting stages required for groups to agree on one of the two options differed substantially by group and session (Appendix Table C.1). While around 55% of group choices were unanimously agreed in the first or second voting stage, 36% of group decisions required at least five voting stages.

RESULT 1: *(i) Hypothesis 2 holds. Most groups implemented the "all rounds" option in each supergame. (ii) Nevertheless, the number of votes required to agree on one option substantially differed by group.*

4.2. The Impact of Democratic Decision-Making

We next move on to identifying the impact of democratic decision-making on subjects' contribution behaviors.[16] We usually need to take care of selection effects for this purpose (e.g. Tyran and Feld 2006, Dal Bó, Foster and Putterman 2010, Kamei 2016a, Dal Bó, Foster and Kamei 2015). However, the collective preference exhibited by almost all groups to commit to a longer partnership from the 1st supergame (RESULT 1) means that the voting process does not create a subsample that is not representative of the population in the ENDO treatment. Therefore, there are little concerns of selection bias when we compare subjects' action choices under the

[16] Because average payoffs are the linear transformations of subjects' contribution amounts based on Eq. (1), results are the same even if the data of their payoffs is instead used.

"all rounds" option in the ENDO treatment against those in the EXO treatment, although we conducted some robustness checks nevertheless, as explained later in this subsection.[17] By contrast, when identifying the effects of democratic decision-making, it may be desirable to control for a possibility of correlation. This is because the duration of voting stages differed by experimental session (Section 4.1). This means that subjects' action choices may be correlated within sessions. For this reason, standard errors are clustered by the session level when individual-level data is used for analyses.

We identify the impact of democratic decision-making by using empirical strategies (a) and (b) as discussed in Section 2. As expected, in each supergame, only the first round is the common period that occurred in the six sessions (see Section 2.1).[18] Thus, we use round 1 behaviors in each supergame to investigate possible democracy effects.

Table 2 provides the average round 1 contribution amounts by treatment and supergame. The average contribution is 10.97 points in the 1st supergame in the ENDO treatment when the groups selected the "all rounds" option, which is greater than that in the EXO treatment (9.19 points). The large difference in the average contribution amount between the two treatments persists until the 5th supergame. In order to study the significance of the impact of democratic decision-making, we conducted regression analyses (Table 3). Columns (1) and (2) of Table 3 includes estimation results using data of the 1st supergame only (1st SG data, hereafter) and of all the five supergames (All SG data, hereafter), respectively. The dependent variable is subject *i*'s contribution amount to the public account in both columns. As for the data of the ENDO treatment, only observations in groups which selected the "all rounds" option are used. The independent variables include the Endo dummy variable, which equals 1 for the ENDO treatment; and 0 otherwise. A tobit regression model is used for the estimation because subjects' contribution amounts are censored at 0 and 20.[19] Standard errors are clustered by session for both

[17] We note that taking care of selection bias is required if a selection through voting occurs unlike our result. See Dal Bó, Foster and Putterman (2010) and Tyran and Feld (2006). Also see Dal Bó, Foster and Kamei (2015), which recently propose a new identification strategy for correcting selection bias in measuring the impact of a democratic process in case of majority rule.

[18] The trends of subjects' round-by-round action choices by session are provided in Appendix Figure C.1. As we had anticipated, the realized length of each indefinitely-repeated game differed substantially by session and supergame in the experiment as often seen in indefinitely-repeated game experiments. For instance, the 1st supergame lasted for only 1 round in three sessions out of six sessions.

[19] One drawback of using a tobit model is that individual random effects cannot be added on top of session clustering. An alternative estimation method to address this concern is to adopt an ordered probit regression model

of the 1st SG data and the All SG data.[20] The specification in column (1) includes only the Endo dummy variable as independent variables since we use action choices in the first supergame as data. In column (2), by contrast, the supergame number variable (which equals 1, 2, 3, 4, or 5) and its interaction with the Endo dummy variable are additionally included in order to control for the trend across the supergames. Estimation results in both columns (1) and (2) indicate that the Endo dummy obtains a significantly positive coefficient for each of the 1st SG and All SG data. This suggests that letting subjects collectively choose the “all rounds” option helps enhance subjects’ contributions significantly.[21]

Subjects’ contribution amounts were very different between groups that selected the “one round” option and ones that selected “all rounds” option. The average contribution amounts of the former groups were much lower than those of the latter groups (Table 2). This is consistent with Hypothesis 1. We note, however, that we are unable to statistically compare the efficiency between the two options because very few groups selected the “one round” option in the ENDO treatment (RESULT 1).

RESULT 2: *(i) Hypothesis 3(a) holds. Subjects contributed significantly more when they democratically implemented the “all rounds” option, compared with when they were exogenously given the same option. This difference remained similar from the first to the last supergame. (ii) Hypothesis 1 holds.*

We note that our results are robust even if we consider a possibility of small selection effects. For instance, as discussed with Table 1, one group selected the “one round” option in the 1st supergame in the ENDO treatment. One may assume that the least cooperative groups may

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because subjects were asked to select one choice among the ordered set: {0, 1, 2, …, 20} as a contribution amount in each round and also because the ordered probit method allows researchers to include both clustering and individual random effects. We estimated the same specifications using ordered probit regression models as a robustness check while including both session clustering and individual random effects. The results, found in Appendix Table C.2, are qualitatively similar to those in Table 3. As a further robustness check, we also ran a linear regression while including both session clustering and individual random effects, which again finds that the results are qualitatively similar to results of Table 2 (the results are omitted to conserve space).

[20] Clustering by session is especially required for the All SG data because the stranger matching protocol is used across the supergames.

[21] Results are similar when session average Mann-Whitney tests are used. The average round 1 contribution in the 1st supergame in the ENDO treatment when the groups selected the “all rounds” option (10.97 points) is significantly higher than that in the EXO treatment (9.19 points) (p = .0495, two-sided). The difference in the average contribution amount is also statistically significant between the two treatments when we use average round 1 contribution amounts across all of the five supergames (p = .0495, two-sided).

have selected the "one round" option and thus the effect of democratic decision-making seen in Tables 2 and 3 may be overestimated. For a robustness check, we conducted a regression whose specification is the same as that in column (1) of Table 3 while excluding one group with the lowest contribution amount in the EXO treatment. As shown in Appendix Table C.4, it was found that the Endo dummy variable obtains a significantly positive coefficient as in column (1) of Table 3. We likewise conducted a robustness check of column (2) of Table 3 as well by dropping group(s) with the lowest contribution amount(s) in other supergames of the EXO treatment; which found that the Endo dummy still obtains a significant coefficient as in column (2) of Table 3 (the results are also included in Appendix Table C.4).

We also note that as shown in Appendix Table C.1, some groups did not unanimously agree on one of the two options even in the last voting stage (i.e., the 20th voting stage). Results in Table 3 change little even if we exclude these groups from regressions (see Appendix Table C.3 for the estimation results).

4.3. Subjects' Beliefs on their Peers' Action Choices – Signaling Effects

A possible factor that may drive RESULT 2 is the effect of signals to cooperate that were sent through voting in the ENDO treatment (e.g., Tyran and Feld 2006). In order to explore this possibility, as an additional analysis we conducted regressions by including subjects' beliefs on their interaction peers' average contribution amount in a given supergame in regressions (columns (3) and (4) of Table 3). Further, the interaction term between the belief variable and the Endo dummy variable was included in order to analyze how the correlation between subject's own contribution amounts and beliefs differ by the presence of the democratic decision process. The estimation results support Hypothesis 3(b). As shown in column (3) of Table 3, the Endo dummy variable no longer obtains a significant coefficient, but instead the belief variable obtains a significantly positive coefficient for the 1st SG data. This implies that the driver of the highly significant effect of the democratic decision process observed in column (1) was subjects' more optimistic beliefs on their interaction peers' contribution amounts in the ENDO treatment, compared with the EXO treatment. Likewise, the same also holds for the All SG data – see column (4) of Table 3.

In order to closely check how subjects' beliefs evolved from supergame to supergame, we also examined the trend of subjects' average beliefs from supergame to supergame (Table 4). First, as is consistent with our discussions in Table 3, it indicated that the average belief in the 1st supergame formed by subjects who selected the "all rounds" option was higher than that formed by subjects who were exogenously given the same option in the EXO treatment. The difference was significant (see column (1), Table 5). This is suggestive of the idea that the effects of signals sent through voting may be large enough to enhance subjects' level of contributions (e.g., Tyran and Feld 2006). Second, however, the average beliefs of subjects who implemented the "all rounds" option in the ENDO treatment declined rapidly from supergame to supergame, and settled at a similar level to the EXO treatment in the 3rd to 5th supergames (see Table 4). A regression analysis indicates that the average beliefs across all supergames are only weakly significantly different between the two treatments when the "all rounds" option is in effect (column (2), Table 5).[22] This rapid decline of beliefs in the ENDO treatment is in contrast with subjects' action choices: subjects' average contribution amounts did not decline very quickly with the democratic decision process (Table 2). These observations on beliefs and action choices mean that democratic decision-making itself may have directly affected the subjects contribution behavior even after the effects of signals sent through voting diminished in the experiment (e.g., Dal Bó, Foster and Putterman 2010, Kamei 2016a), as in Hypothesis 3(c).

RESULT 3: *Beliefs on interaction peers' contribution amounts formed by subjects who collectively selected the "all rounds" option were significantly higher than ones formed by subjects who were given the same option in the EXO treatment in the 1st supergame. However, the beliefs reach similar levels between the two treatments in the 3rd to 5th supergames unlike the contribution dynamics summarized in RESULT 2.*

4.4. The Number of Voting Stages to Reach a Consensus and Subjects' Decisions to Contribute

As mentioned earlier, the number of voting stages required to reach a consensus differed by group (Appendix Table C.1). How did the differences in the voting length affect subjects'

[22] This weak significant result is not robust. The Endo dummy variable fails to obtain a significant coefficient if an ordered probit regression, instead of the tobit regression model, is used. The average beliefs across all supergames are not significantly different between the two treatment also according to Mann-Whitney tests (*p*-value = .2752, two-sided).

belief formation and action choices? We explore this sub-question by conducting a regressions analysis using the 1st supergame.[23]

As shown in Appendix Table C.6, we find two interesting results. First, regardless of the numbers of voting stages required for groups to reach an agreement, democratic decision-making enhances subjects' beliefs on their interaction peers' contribution amounts (Panel (2) of Table C.6). This implies that voting opportunities are indeed helpful for subjects to signal their future intention to cooperate, as shown in Tyran and Feld (2006). Second, however, subjects' contribution behaviors largely depend on the number of voting stages required to reach an agreement. In the ENDO treatment, out of 15 groups that implemented the "all rounds" option, the number of groups that underwent one voting stage, two voting stages, three voting stages, seven voting stages and 20 voting stages are five, six, two, one and one group(s), respectively. As is consistent with RESULT 2, subjects' contribution amounts were significantly higher in groups that underwent small number of voting stages for reaching a consensus, compared with groups in the EXO treatment (Panel (1) of Table C.6). However, subjects contributed significantly less to the public good when they had to spend all voting stages in order to reach an agreement compared with subjects in the EXO treatment. The latter result may mean that the democratic decision process alone is not enough to persuade some very uncooperative subjects to cooperate even though the "all rounds" option is imposed in the last voting stage. This result is similar to Dal Bó, Foster and Putterman (2010) and Kamei (2016a) where majority rules were used. In Dal Bó, Foster and Putterman (2010) and Kamei (2016a), only supporters of a policy exhibit the positive effects of democratic decision-making.[24]

RESULT 4: *Democratic decision-making enhanced subjects' beliefs, regardless of how many voting stages subjects spent for an agreement. Democratic decision-making raised subjects' contributions only in groups that underwent small number of voting stages for getting a consensus.*

[23] Data of the 2nd to 5th supergame was not included in this analysis in order to avoid the analysis become too complicated. In addition to the difference in the number of voting stages in the 1st supergame, subjects' experiences (the number of allocation stages) in earlier supergames also differed by sessions as mentioned earlier, which would make the analysis complex.

[24] In Tyran and Feld (2006), both supporters and opponents of a policy in the endogenous regime raised their level of contributions, compared with the exogenous regime. The difference in subjects' behavior between these past studies may be caused by the difference in culture or norms (e.g., the United States versus Switzerland).

5. Collective Decision-Making with Majority Rule

We found that almost all groups prefer to play with specific others, rather than random others, even though any symmetric contribution situation holds as an equilibrium outcome in both regimes. We also found that democratic selection of interaction durations may enhance cooperation, compared with the environment where interaction durations are exogenously given, as is similar to past studies on democracy (e.g., Tyran and Feld 2006, Dal Bó, Foster and Putterman 2010, Kamei 2016a, Sutter, Haigner and Kocher 2010). Some democratic decision-making takes a form other than unanimity rule, such as majority rule. Would the key results we summarized in Section 4 change if a different voting rule is used? Recent experimental work on democracy – Tyran and Feld (2006), Dal Bó, Foster and Putterman (2010), and Kamei (2016a), used majority rule, rather than unanimity rule, unlike Sutter, Haigner and Kocher (2010). In order to check the robustness of our findings in Section 4, we designed an additional treatment by changing the decision rule from the unanimity rule to a majority rule. That is, whichever option ("all rounds" or "one round") receives more than two votes is implemented in a group. When the votes are split in half, the computer randomly breaks the tie. We note that unlike the ENDO treatment, the duration of the voting stage is one for every group in each session. Thus, group-level data could be considered as the unit of independent observations in the 1st supergame. We call this additional treatment the "ENDO-Majority" treatment ("Endogenous, Majority Rule" treatment). The design pieces other than the collective decision rule are identical to those of the ENDO treatment (the instructions of the ENDO-Majority treatment are available in Section D.1 of Appendix D).

We conducted three sessions of the ENDO-Majority treatment in October 2016 in the EXEC laboratory at the University of York. The experimental procedure, including recruiting subjects, is the same as that in the original two treatments. A total of 64 subjects participated in the additional treatment. The number of subjects per session was 20 or 24, and they were broken into 5 or 6 groups. The average per-subject payoff (including £3 for participation fee) was 16.41 pounds sterling. The results of this treatment are very similar to those in the ENDO treatment as will be explained in this section.

First, Result 1(i) holds also for the ENDO-Majority treatment. Table 1 reports the number of groups that collectively selected the "all rounds" option by supergame. It indicates that 15 out of 16 groups in the ENDO-Majority treatment collectively implemented the "all rounds" option, as is the case in the ENDO treatment. After the first supergame, slightly smaller numbers of groups, 10 to 13 groups, collectively selected the "all rounds" option in each supergame in this treatment. However, the difference in the fraction of groups that selected the "all rounds" option between the two endogenous treatments is not significantly different in each supergame (see Appendix Table D.1).

RESULT 5: *Result 1(i) holds for the ENDO-Majority treatment. That is, the majority of groups selected the "all rounds" option in the ENDO-Majority treatment.*

Second, we find significantly positive impact of democratic decision-making on subjects' contribution behaviors in the ENDO-Majority treatment. We apply empirical strategies (a) and (b) for the data of the ENDO-Majority treatment. As expected because of our experimental design setting, in each of the five supergames, only the first period is the common period across all of the three sessions of the ENDO-Majority treatment and the three sessions of the EXO treatment.[25] We use round 1 contribution behaviors in the analysis to have high statistical power. In the rest of Section 5, without stating otherwise, the average cooperation behaviors of individual subjects, sessions or treatments are calculated based on the first round of each supergame. Table 6 reports the average contributions and beliefs in the ENDO-Majority treatment. Along with Table 2, it indicates that the average contributions with the "all rounds" option in the ENDO-Majority treatment are 35.7%, 30.4%, 25.4%, 36.6%, and 34.8% higher than those in the EXO treatment in the 1st, 2nd, 3rd, 4th and 5th supergames, respectively. As shown in Appendix Table D.2, the difference in the average contribution between the two treatments is significant, regardless of which empirical strategy (a) or (b) is used.[26]

The strong impact of democratic decision-making is not due to selection bias. We performed a robustness check for the results shown in Panel (a) of Table 6 and Appendix Table D.2, considering possible selection effects (e.g., Dal Bó, Foster and Putterman 2010, Dal Bó,

[25] The period-by-period trend of average contributions by session can be found in Appendix Figure D.1.

[26] Analyses in Appendix Table D.2 are based on the regressions as we performed in Table 3 for the ENDO treatment. The differences are significant also when Mann-Whitney tests are used. First, the difference in the average contribution under the "all rounds" option is significantly different between the ENDO-Majority and EXO treatment in the first supergame (two-sided p-value = .0126 if group-average data is used; two-sided p-value = .0495 if session-average data is used). Second, the difference is significant also when the All SG data is used (two-sided p-value = .0495 using session-average data).

Foster and Kamei 2015, Kamei 2016a, Tyran and Feld 2006). Specifically, as in Section 4.2, assuming that groups that collectively selected the “one round” option in the ENDO-Majority treatment are the least cooperative groups, we drop the same number of groups with the smallest contributions from the EXO treatment. As detailed in Appendix Table D.3, the result of the positive impact of democratic decision-making is little affected by the omission of the least cooperative group(s) in each supergame from the EXO treatment.

A driver of the strong contribution behavior in the ENDO-Majority treatment is the impact of democratic decision-making on subjects’ beliefs, as is the case for unanimity voting. Panel (b) of Table 6 indicates that the average beliefs with the “all rounds” option in the ENDO-Majority treatment is always higher, compared with those in the EXO treatment in Table 4. As shown in Appendix Table D.2 and Table D3, once the subjects’ beliefs are controlled for, the difference in the subjects’ average contribution behaviors is no longer significant between the ENDO-Majority and EXO treatments. This implies that the function of majority voting through which subjects can send signals to their peers is indeed effective in enhancing cooperation (e.g., Tyran and Feld 2006).

RESULT 6: *Democratic decision-making enhanced both subjects’ contribution amounts and beliefs when the majority rule was used, as is the case when unanimity rule was used.*

In Section 4.4, we found that the impact of democratic decision-making depends on the agreement process (Result 4). The data of the ENDO-Majority treatment shows similar results. Figure 2 reports the average contribution and belief with the “all rounds” option by the number of voters that supported the “all rounds” option. It indicates that the higher percentage of support a group have for implementing the “all rounds” option, the higher average contribution they achieve. Especially, when all four members support the partner matching option, the average contributions are 58.6% and 60.3% higher than those in the EXO treatment in the 1st SG data and All SG data, respectively (Figure 2). However, the differences in the average contribution between the two treatments drastically shrink when not all members vote for the “all rounds” option. Subjects’ beliefs, reported in Panel (b) of Figure 2, are parallel to the results of contribution behaviors. These results resonate with the idea that signals sent through voting drives the higher cooperation behavior also in the ENDO-Majority treatment.

Lastly, an exploration of contribution behavior with the “all rounds” option by voter type shows correlations between their votes and subsequent contribution behaviors. Panel (a) of Table 6 includes the average contribution by those who voted for the “all rounds” option (the “yes voters,” hereafter) and those who voted against it (the “no voters,” hereafter). It indicates the average contribution amount of the yes voters is 79.5% higher than that of the no voters in the 1st supergame. The difference between the two voter types diminishes in the second supergame; this could result from the no voters’ learning to mimic the behavior of the yes voters. But, the average contribution of the yes voters is higher than that of the no voters in each supergame after the second supergame. Regression analyses, shown in Appendix Table D.7, found that the average contribution of the yes voters is significantly stronger than that of the no voters, whether the 1st SG data or the All SG data is used. The trend of average beliefs (Panel (b), Table 6) is similar to that of average contributions. Once subjects’ beliefs are controlled for, the impact of democratic decision-making diminishes to a large degree (even-numbered columns in Appendix Table D.7). This implies that the important channel that boosts contributions in the additional experiment was the yes voters’ enhanced beliefs on the contribution behavior of their interaction partners with the “all rounds” option.

RESULT 7: *The higher percentage of support a group had when implementing the “all rounds” option, the higher contribution situation the group achieved in the ENDO-Majority treatment.*

RESULT 8: *The yes voters contributed significantly more than the no voters when the “all rounds” option was implemented in the ENDO-Majority treatment.*

6. Conclusions

This paper explored whether people collectively prefer to play with each other in a partner matching or random matching environment and whether a collective choice to interact with the same players may mitigate subjects’ uncooperative behavior. Our experiment, whose framework is a linear public goods game, provides affirmative answers to both of the questions. First, most groups selected an option under which the members indefinitely played with each other under the partner matching protocol. Second, subjects’ level of contributions was significantly higher when they decided to repeatedly interact with each other by votes than when they were given the same rule exogenously. Our analyses indicated that the impact of democratic decision-making is not due to selection bias, but could be due to signaling effects in the collective decision process: the voting process enhances the subjects' beliefs on their peers' contribution acts. The importance of democratic decision-making on behavior is similar to recent findings in the experimental literature (e.g. Tyran and Feld 2006, Dal Bó, Foster and Putterman 2010, Sutter, Haigner and Kocher 2010), and is the first demonstration in the context of indefinitely-repeated situations.

Further, we conducted an additional treatment with majority voting rule to check the robustness of the findings based on the unanimity rule. The additional data replicates qualitatively almost the same results when the majority rule is used. This implies that our results can be robust to democratic decision rules. Nevertheless, we acknowledge that there are many other forms of democracy, such as super-majority rule and plurality rule, and thus robustness check of our findings using other voting rules could be useful.

As a final remark, we note that our paper also has a broad implication for experimental research on infinitely-repeated dilemma games. Experimental work to explore a possibility of cooperation is usually designed so that the basic rules of a game, such as continuation probability and matching protocols, are pre-determined without having endogenous features. This paper shows that letting subjects collectively select to play with the same players under the shadow of the future may enhance people's contribution behavior significantly in indefinitely-repeated collective action dilemmas. This implies that people's behavior and equilibrium selection may be largely affected by the way in which the basic rules of game are given (endogenously versus exogenously).

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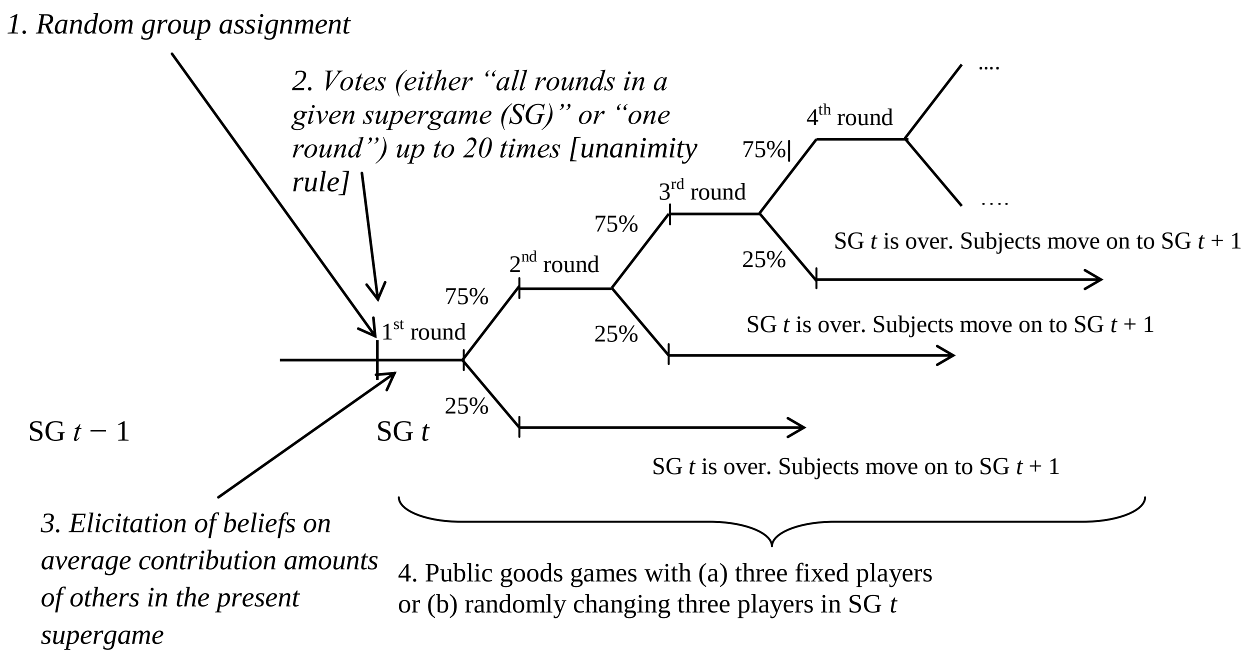
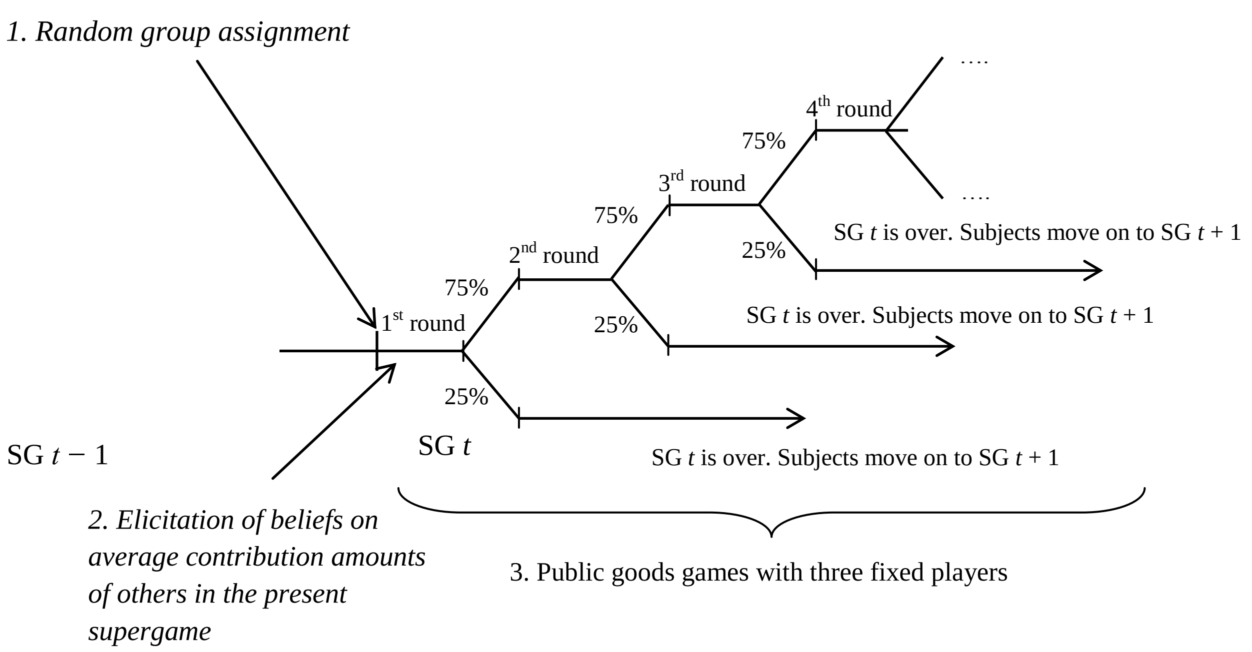
Figure 1: *Experimental Design*



(a) The ENDO treatment



(b) The EXO treatment

Table 1: *Summary of Treatments*

Treatment name	Grouping (Matching Protocol)	The way in which grouping is decided in a group	The number of groups that selected "all rounds" option[1]					The # of subjects (sessions)
			1st SG	2nd SG	3rd SG	4th SG	5th SG	
[Main treatments]								
ENDO (Endogenous)	Partner or Random	Unanimity Voting	15 [16]	15 [16]	11 [16]	14 [16]	15 [16]	64 (3)
EXO (Exogenous)	Partner	Always partner matching	----	----	----	----	----	68 (3)
[Additional treatment]								
ENDO-Majority (Endogenous, Majority rule)[2]	Partner or Random	Majority Voting	15 [16]	13 [16]	13 [16]	10 [16]	12 [16]	64 (3)
Total								196 (9)

Notes: [1] The numbers in the squared brackets indicate the total numbers of groups. We use the term SG as the abbreviation of supergame.

[2] The ENDO-Majority treatment is an additional treatment to supplement the findings obtained in the main treatments. See Section 5 for the description of the ENDO-Majority treatment.

Table 2: *Contribution Amounts in Each Supergame*

	Supergame 1	Supergame 2	Supergame 3	Supergame 4	Supergame 5	All Supergames
(a) The ENDO treatment						
Session 1						
All rounds option	10.96 (6)	9.95 (5)	8.67 (3)	6.67 (6)	5.96 (6)	8.36
One round option	N/A (0)	4.75 (1)	5.50 (3)	N/A (0)	N/A (0)	5.31
Session 2						
All rounds option	11.19 (4)	11.35 (5)	10.00 (5)	8.94 (4)	9.85 (5)	10.28
One round option	0.25 (1)	N/A (0)	N/A (0)	0.50 (1)	N/A (0)	0.38
Session 3						
All rounds option	10.80 (5)	9.45 (5)	6.08 (3)	8.25 (4)	9.50 (4)	9.07
One round option	N/A (0)	N/A (0)	2.75 (2)	2.00 (1)	0.75 (1)	2.06
Average						
All rounds option	10.97 (15)	10.25 (15)	8.57 (11)	7.77 (14)	8.20 (15)	9.20
One round option	0.25 (1)	4.75 (1)	4.40 (5)	1.25 (2)	0.75 (1)	3.03
(b) The EXO treatment						
Session 4						
All rounds option	8.29	8.42	7.54	7.96	6.67	7.78
Session 5						
All rounds option	9.58	6.83	6.42	5.67	6.17	6.93
Session 6						
All rounds option	9.80	9.50	8.10	6.80	7.55	8.35
Average						
All rounds option	9.19	8.18	7.31	6.81	6.75	7.65

Notes: Each session consists of five or six groups. The numbers in parentheses are the numbers of groups that operated in the regime in the first column of the corresponding row as a result of voting outcomes. The average contributions were calculated using subjects' round 1 behavior in each supergame and session. The trends of contribution amounts after the first round of each supergame are found in Appendix Figure C.1.

Table 3: *The Effects of Democratic Decision-Making on Enhancing Cooperation*

Dependent variable: Contribution amount of subject *i* in round 1 of a given supergame

Data: Independent Variable:	1st Supergame (1)	All Supergames (2)	1st Supergame (3)	All Supergames (4)
(i) Endo Dummy {= 1 for the ENDO treatment; 0 otherwise}	2.42*** (.78)	3.13*** (1.15)	1.85 (3.29)	-.082 (1.51)
(ii) Supergame Number {= 1, 2, 3, 4, 5}	---	-0.90*** (.14)	---	.077 (.084)
Interaction term: (i) × (ii)	---	-.41 (.49)	---	-.075 (.36)
(iii) Subject *i*'s belief on her peers' avg. contribution	---	---	1.19*** (.30)	.98*** (.15)
Interaction term: (i) × (iii)	---	---	-.075 (.34)	.19 (.16)
Constant	9.46*** (.74)	9.77*** (.44)	-2.22 (2.97)	-.88 (1.62)
# of observations	128	620	128	620
Log likelihood	-356.1	-1702.6	-329.2	-1635.0
F	9.67	16.57	25.84	261.03
Prob > F	.0023	.0000	.0000	.0000

Notes: Tobit regressions with robust standard errors clustered by session ID. Observations only in groups that operated under the "all rounds" option in each supergame are used. The numbers in parentheses are standard errors. The numbers of left-(right-)censored observations are 16(29) in columns (1) and (3) and 129(100) in columns (2) and (4).

As a robustness check, we also conducted individual random-effects ordered probit regressions with standard errors clustered by session ID. The results, included in Appendix Table C.2, are qualitatively similar to Table 3. We also note that individual random-effects linear regression with standard errors clustered by session ID also generate qualitatively similar results (the results are omitted to conserve space).

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Table 4: *Beliefs on Matched Partners' Average Contribution Amounts in Each Supergame*

	1st Supergame	2nd Supergame	3rd Supergame	4th Supergame	5th Supergame	All Supergames
(a) The ENDO treatment						
Session 1						
All rounds option	11.63 (6)	11.10 (5)	7.58 (3)	6.92 (6)	6.83 (6)	8.87
One round option	N/A (0)	7.75 (1)	4.58 (3)	N/A (0)	N/A (0)	5.38
Session 2						
All rounds option	10.25 (4)	8.40 (5)	7.10 (5)	6.00 (4)	6.50 (5)	7.61
One round option	3.25 (1)	N/A (0)	N/A (0)	0.75 (1)	N/A (0)	2.00
Session 3						
All rounds option	11.15 (5)	10.90 (5)	7.75 (3)	7.44 (4)	7.44 (4)	9.10
One round option	N/A (0)	N/A (0)	8.125 (2)	2.75 (1)	2.75 (1)	5.44
Average						
All rounds option	11.10 (15)	10.13 (15)	7.41 (11)	6.80 (14)	6.88 (15)	8.57
One round option	3.25 (1)	7.75 (1)	6.00 (5)	1.75 (2)	2.75 (1)	4.34
(b) The EXO treatment						
Session 4						
All rounds option	9.63	9.67	8.04	6.67	7.29	8.26
Session 5						
All rounds option	8.83	8.17	7.67	4.46	4.58	6.74
Session 6						
All rounds option	11.10	9.40	8.35	8.50	6.60	8.79
Average						
All rounds option	9.78	9.06	8.00	6.43	6.13	7.88

Notes: Each session consists of five or six groups. The numbers in parentheses are the numbers of groups that operated in the regime in the first column of the corresponding row as a result of voting outcomes.

Table 5: *The Effects of Democratic Decision-Making on the Formation of Subjects' Beliefs*

Dependent variable: Belief of subject *i* on his or her three interaction partners' average contribution amount in a given supergame

Data: Independent Variable:	1st supergame (1)	All Supergames (2)
(i) Endo Dummy {= 1 for the ENDO treatment; 0 otherwise}	1.61** (.74)	1.40* (.77)
(ii) Supergame Number {= 1, 2, 3, 4, 5}	---	-1.03*** (.14)
Interaction term: (i) × (ii)	---	-.24 (.17)
Constant	9.85*** (.66)	11.0*** (.37)
# of observations	128	620
Log Pseudo likelihood	-373.5	-1764.6
F	4.77	248.9
Prob > F	.0309	.0000

Notes: Tobit regressions with robust standard errors clustered by session ID. The numbers of left-(right-) censored observations are 4(14) and 22(23) in columns (1) and (2), respectively. As for the ENDO treatment, only observations in groups which selected the "all rounds" option are used. The numbers in parentheses are standard errors.

As a robustness check, we also conducted individual random-effects ordered probit regressions with standard errors clustered by session ID. The Endo Dummy in the specification of column (1) obtains a significantly positive coefficient as in Table 5. The Endo Dummy in the specification of column (2) obtains a positive, but insignificant, coefficient in the ordered probit regression. The results are included in Appendix Table C.5.

We also conducted individual random-effects linear regression with standard errors clustered by session ID also; which generates qualitatively similar results to Appendix Table C.5 (the results are omitted to conserve space).

*, **, and *** indicate significance at the .10 level, at the .05 level and at the .01 level, respectively.

Table 6: *Contribution Amounts and Beliefs in the ENDO-Majority Treatment*

(a) Average Contribution Amounts

	Supergame 1	Supergame 2	Supergame 3	Supergame 4	Supergame 5	All Supergames
Additional Session 1						
All rounds option	12.44 (4)	9.44 (4)	6.83 (3)	6.42 (3)	7.00 (3)	8.72
One round option	9.00 (1)	3.25 (1)	5.88 (2)	11.25 (2)	6.00 (2)	7.31
Additional Session 2						
All rounds option	11.50 (5)	11.25 (4)	9.06 (4)	12.17 (3)	10.31 (4)	10.83
One round option	n.a. (0)	7.75 (1)	4.75 (1)	4.75 (2)	1.25 (1)	4.65
Additional Session 3						
All rounds option	13.29 (6)	11.20 (5)	10.42 (6)	9.31 (4)	9.40 (5)	10.87
One round option	n.a. (0)	6.50 (1)	n.a. (0)	8.75 (2)	5.00 (1)	7.25
Average						
All rounds option	12.47 (15)	10.67 (13)	9.17 (13)	9.30 (10)	9.10 (12)	10.27
Those who voted for "all rounds" option	*13.25*	*10.24*	*9.73*	*10.28*	*9.77*	*10.83*
Those who voted for "one round" option	*7.38*	*11.86*	*7.33*	*5.38*	*6.22*	*8.08*
One round option	9.00 (1)	5.83 (3)	5.50 (3)	8.25 (6)	4.56 (4)	6.51
Those who voted for "all rounds" option	*10.00*	*7.20*	*2.00*	*8.10*	*3.13*	*5.73*
Those who voted for "one round" option	*8.00*	*4.86*	*8.00*	*8.36*	*6.00*	*7.13*

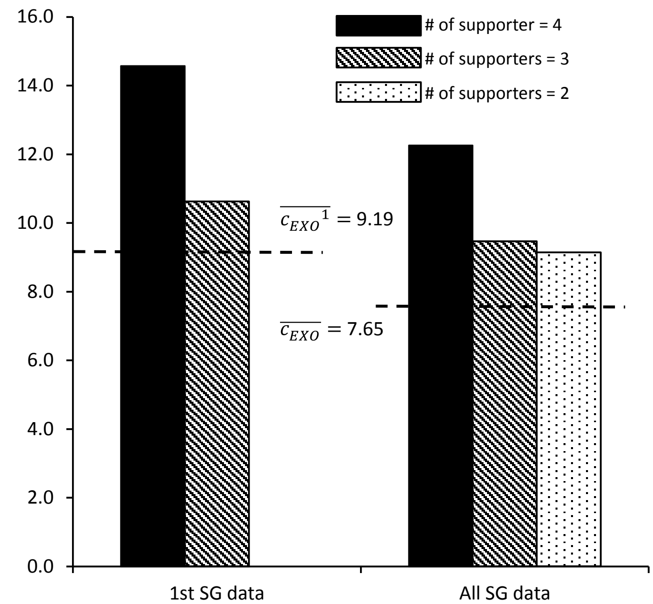
Notes: Each session consists of five or six groups. The numbers in parentheses are the numbers of groups that operated in the regime in the first column of the corresponding row as a result of voting outcomes. The average contributions were calculated using subjects' round 1 behavior in each supergame and session. See Part (b) of Table 2 for the average contribution amounts in the EXO treatment to see the difference between the ENDO-Majority and EXO treatments. Appendix Tables D.2 and D.3 show statistical significance of the impact of democratic decision-making on subjects' contribution behavior when majority rule is used.

(b) Average Beliefs

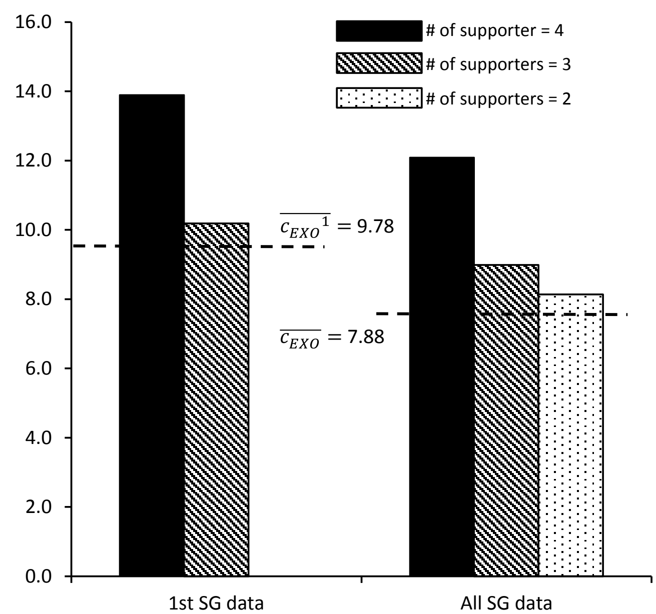
	Supergame 1	Supergame 2	Supergame 3	Supergame 4	Supergame 5	All Supergames
Additional Session 1						
All rounds option	10.00 (4)	8.44 (4)	8.33 (3)	6.83 (3)	7.58 (3)	8.35
One round option	5.00 (1)	7.25 (1)	4.63 (2)	9.38 (2)	5.88 (2)	6.50
Additional Session 2						
All rounds option	11.65 (5)	10.88 (4)	10.13 (4)	8.58 (3)	10.88 (4)	10.58
One round option	n.a. (0)	8.25 (1)	5.00 (1)	6.88 (2)	2.50 (1)	5.90
Additional Session 3						
All rounds option	13.42 (6)	12.1 (5)	9.92 (6)	8.25 (4)	6.50 (5)	10.23
One round option	n.a. (0)	5.25 (1)	n.a. (0)	7.25 (2)	8.75 (1)	7.13
Average						
All rounds option	11.72 (15)	10.30 (13)	9.47 (13)	8.36 (10)	8.27 (12)	9.67
Those who voted for "all rounds" option	*12.65*	*10.55*	*10.15*	*8.78*	*8.69*	*10.37*
Those who voted for "one round" option	*7.13*	*10.71*	*7.83*	*4.50*	*6.22*	*7.71*
One round option	6.00 (1)	7.40 (3)	6.30 (3)	6.39 (6)	6.50 (4)	6.47
Those who voted for "all rounds" option	*2.50*	*6.20*	*2.00*	*8.00*	*5.00*	*5.53*
Those who voted for "one round" option	*7.50*	*7.43*	*6.71*	*7.71*	*6.50*	*7.21*

Notes: Each session consists of five or six groups. The numbers in parentheses are the numbers of groups that operated in the regime in the first column of the corresponding row as a result of voting outcomes. See Part (b) of Table 4 for the average beliefs in the EXO treatment to see the difference between the ENDO-Majority and EXO treatments. Appendix Table D.4 shows statistical significance of the impact of democratic decision-making on subjects' beliefs in the first supergame when majority rule is used.

Figure 2: *Average Contributions and Beliefs in the "All Rounds" Option in the ENDO-Majority Treatment by the Number of Supporters.*



(a) Average contributions by the number of supporters[#1]



(b) Average beliefs on peers' contribution amounts by the number of supporters

Notes: $\overline{c_{EXO}}^1$ is the average round 1 contribution (average belief) in the first supergame in the EXO treatment in graph (a) (graph (b)). $\overline{c_{EXO}}$ is the average round 1 contribution (average belief) in all supergames in the EXO treatment in graph (a) (graph (b)). [#1] There are zero cases where the number of support was two and the computer randomly implement the "all rounds" option in the first supergame.

Appendix B: Theoretical Consideration for Groups that Collectively Select the "One round" Option in the ENDO treatment

In this part of the Appendix, we first show that the mutual full contribution situation holds as an equilibrium outcome (Section B.1). We then illustrate that there also exists a symmetric, positive less-than-full-contribution equilibrium for any contribution level $\xi \in \{1, 2, \ldots, 19\}$ (Section B.2)**.**

B.1. *Mutual Full Contribution Equilibrium*

In order to illustrate that there are no incentives to deviate from the mutual full contribution situation, we consider a very extreme case in which all groups in a session, six groups, selected the "one round" option in the ENDO treatment and all subjects that are in these groups have contributed full endowment amount (*E*) so far (before round *t*) in a given round. We also suppose that subjects have acted on a grim trigger strategy until this round. We show that even in this situation subject *i* decides not to defect. This suggests that the mutual full contribution equilibrium exists for every possible situation as to the number of groups that selected the "one round" option ($\in\{1, 2, 3, 4, 5, 6\}$). This is because the more groups select the "one round" option in a given supergame, the higher the incentive for a subject *i* to deviate in that supergame is because *i* can more easily engage in the hit-and-run strategy (defect and then escape from the group members) if more groups select the "one round" option.

Suppose that the subject *i*'s three peers and all subjects in other groups that selected the "one round" option continue to choose the grim trigger strategy in round *t* and onward in a given supergame.

If subject *i* also continues to act on the grim trigger strategy until the given supergame is over, she would obtain the following expected payoff for the rest of rounds:

$$E_t[\pi_i] = \sum_{s=t}^{\infty} \delta^{s-t} \cdot \pi_{i,t}(c_{i,t}) = \frac{r \cdot N \cdot E}{1-\delta} = 128, \qquad \text{(B1)}$$

where $\delta = .75$, $r = .4$, $N = 4$ and $E = 20$.

Step 1: *There are no incentives for subject i to contribute 0 points in round t and then return to full contribution in round t + 1*

Suppose that i contributes 0 points in round t but returns to full contribution in round t + 1. In this scenario, subject i obtains $E - 0 + r \cdot (N - 1) \cdot E = 44$ points in round t. The expected payoff of subject i in round t + 1 is computed as:

$$E_t[\pi_{i,t+1}] = 32 \cdot \frac{\binom{20}{3}\binom{3}{0}}{\binom{23}{3}} + 24 \cdot \frac{\binom{20}{2}\binom{3}{1}}{\binom{23}{3}} + 16 \cdot \frac{\binom{20}{1}\binom{3}{2}}{\binom{23}{3}} + 8 \cdot \frac{\binom{20}{0}\binom{3}{3}}{\binom{23}{3}} \approx 28.8696. \quad \text{(B2)}$$

After round t + 1, any subject that encounters at least one 0-contributor in round t, round t + 1 or later rounds also becomes a 0-contributor. The three peers of subject i in round t are 0-contributors in round t + 2 with a probability of 100%. The probability that a subject j in a group to which subject i's did not belong in round t does not become a 0-contributor in round t + 2 is calculated as:

$$p \equiv \frac{\binom{20}{3}\binom{3}{0}}{\binom{23}{3}} = \frac{1140}{1771} \approx 64.37\%,$$

because the number of full contributors except j in round t + 1 is 20. Here, we claim that the probability that j remains to be a full contributor in round t + 3 (p') is less than 12%, regardless of i's action choices in round t + 2 as below:

Claim: $p' < .12$.

When i contributed E points in round t + 2,

$$p' \equiv p \cdot \frac{p^3\binom{19}{3}\binom{3}{0} + 1 \cdot p^2\binom{19}{2}\binom{3}{0}}{\binom{23}{3}} = .1197 < .12.$$

When i contributed 0 points in round t + 2,

$$p' \equiv p \cdot \frac{p^3\binom{19}{3}\binom{3}{0}}{\binom{23}{3}} = .0939 < .12.$$

This calculation indicates that $p' < .12$. ■

Subject i would obtain the largest per-round payoff in round t + 2 when i contributes 0 points in round t + 2:

$$E_t[\pi_{i,t+2}]\Big|_{c_{i,t+2}=0} = 20 + 8 \cdot \left[(3p^3 + 2p^2(1-p) + p(1-p)^2) \cdot \frac{\binom{20}{3}\binom{3}{0}}{\binom{23}{3}} + \left(2p^2 + p(1-p)\right)\frac{\binom{20}{2}\binom{3}{1}}{\binom{23}{3}} + p \cdot \frac{\binom{20}{1}\binom{3}{2}}{\binom{23}{3}}\right], \quad \text{(B3)}$$

which equals 28.961.

The per-round expected payoff that subject *i* obtains after round $t + 2$ is less than round $t + 3$ expected payoff when *i* contributed 0 points while assuming $p' = .12$, whose payoff is equal to around 21.014 (this value is obtained by evaluating Eq. (B3) by substituting $p = .12$). Thus, we have the following inequality for *i*'s after round $t + 2$:

$$E_t\left[\sum_{s=t+3}^{\infty} \delta^{s-t} \cdot \pi_{i,t}\right] \ll \frac{\delta^3}{1-\delta} E_t\left[\pi_{i,t+3}\right] < \max \frac{\delta^3}{1-\delta} E_t\left[\pi_{i,t+3}\right] < \frac{(.75)^3 \cdot 21.014}{1-.75} \approx 35.46.$$

Therefore,

$$E_t[\pi_i] = E_t\left[\sum_{s=t}^{\infty} \delta^{s-t} \cdot \pi_{i,t}\right] \ll 44 + \delta \cdot 28.87 + \delta^2 \cdot 28.96 + 35.46 = 117.4, \quad \text{(B4)}$$

which is lower than the sum of total expected payoffs under the mutual full contribution situation calculated in Eq. (B1). This means that contributing 0 points in round *t* and then returning to full contribution in round $t + 1$ is not the best response for subject *i*.

Step 2: *There are no incentives for subject i to contribute 0 points in both round t and round t + 1*

Suppose that subject *i* contributes 0 points in round $t + 1$, in addition to round *t*. Then, the expected payoff of subject *i* in round $t + 1$ is computed as:

$$E_t\left[\pi_{i,t+1}\right] = 20 + \left[24 \cdot \frac{\binom{20}{3}\binom{3}{0}}{\binom{23}{3}} + 16 \cdot \frac{\binom{20}{2}\binom{3}{1}}{\binom{23}{3}} + 8 \cdot \frac{\binom{20}{1}\binom{3}{2}}{\binom{23}{3}}\right] \approx 40.8696. \quad \text{(B5)}$$

The probability that a subject *j* in a group to which subject *i* did not belong in round *t* does not become a 0-contributor in round $t + 2$ is:

$$q = \frac{\binom{19}{3}\binom{3}{0}}{\binom{23}{3}} = \frac{969}{1771} = 54.71\% < 54.75\%,$$

because the number of full contributors other than *j* in round $t + 1$ is 19. Thus, subject *i*'s expected payoff in round $t + 2$ is less than or equal to the value of Eq. (B3) evaluated at $p = q = .5475$: i.e., $E_t\left[\pi_{i,t+2}\right] < 26.84$.

Here, we claim that the probability that *j* remains to be a full contributor in round $t + 3$ (q') is less than 6.49%, regardless of *i*'s action choice in round $t + 2$.

Claim: $q' < .0649$.

When i contributed E points in round $t + 2$,

$$q' \equiv q \cdot \frac{q^3\binom{19}{3}\binom{3}{0}+q^2\binom{19}{2}\binom{3}{0}}{\binom{23}{3}} = .06485 < .0649.$$

When i contributed 0 points in round $t + 2$,

$$q' \equiv q \cdot \frac{q^3\binom{19}{3}\binom{3}{0}}{\binom{23}{3}} = .049 < .05.$$

This calculation indicates that $q' < .0649$. ■

The per-round expected payoff that subject i obtains after round $t + 2$ is less than her round $t + 3$ expected payoff when i contributed 0 points in round $t + 3$ while assuming $q' = .0649$, whose payoff is equal to around 20.53 (this value is obtained by evaluating Eq. (B3) by substituting $p = q' = .0649$). Thus, we have the following inequality for i's payoffs after round $t + 2$:

$$E_t\left[\sum_{s=t+3}^{\infty} \delta^{s-t} \cdot \pi_{i,t}\right] \ll \frac{\delta^3}{1-\delta} E_t\left[\pi_{i,t+3}\right] < \frac{(.75)^3 \cdot 20.53}{1-.75} \approx 34.65.$$

In other words, we obtain the following strict inequality:

$$E_t[\pi_i] = E_t\left[\sum_{s=t}^{\infty} \delta^{s-t} \cdot \pi_{i,t}\right] \ll 44 + \delta \cdot 40.87 + \delta^2 \cdot 26.84 + 34.65 \approx 124.40. \quad \text{(B6)}$$

This expected payoff (left-hand side) is lower than the sum of expected payoffs in the mutual full contribution situation calculated in Eq. (B1). This means that contributing 0 points in both rounds t and $t + 1$ is not a materially beneficial deviation for subject i.

The Steps 1 and 2 suggest that the mutual full contribution situation holds as an equilibrium outcome.

B.2. *Symmetric, Positive, but Less-than-full-Contribution Equilibrium*

Similar calculations as in Section B.1 show that there also exists a symmetric, positive, but less-than-full-contribution equilibrium for each contribution level $\xi \in \{1, 2, \ldots, 19\}$. The following table indicates the summary of the calculations. For each level ξ, we considered the two cases (Step 1 and Step 2) as in Section B.1.

ξ	Total expected payoff from symmetric, positive contribution equilibrium with the level of ξ points (= $E + (rN - 1)\xi/(1 - \delta)$)	The supremum of the expected payoff when i contributes 0 in round t and then returns to contribute ξ points in round $t + 1$ (Eq.(4), included in step 1 above, calculated for each ξ points)	The supremum of the expected payoff when i contributes 0 in both rounds t and $t + 1$ (Eq.(6), in step 2 above, calculated for each ξ points)
1	82.4	81.9	82.2
2	84.8	83.7	84.4
3	87.2	85.6	86.7
4	89.6	87.5	88.9
5	92.0	89.4	91.1
6	94.4	91.2	93.3
7	96.8	93.1	95.5
8	99.2	95.0	97.8
9	101.6	96.8	100.0
10	104.0	98.7	102.2
11	106.4	100.6	104.4
12	108.8	102.4	106.6
13	111.2	104.3	108.9
14	113.6	106.2	111.1
15	116.0	107.3	113.3
16	118.4	109.9	115.5
17	120.8	111.8	117.7
18	123.2	113.7	112.0
19	125.6	115.5	122.2
20	128.0[#1]	117.4[#2]	124.4

Notes: [#1] This is the case of the full contribution equilibrium (see Section B.1 for the details). The payoff was calculated with Eq. (B1). [#2] This was calculated with Eq. (B4).

This table indicates that deviating from contributing ξ points is not materially beneficial for each subject, assuming that all of their peers are employing the grim trigger strategy in that they contribute ξ points until they observe that at least one of peers contribute less than ξ points; and once they see such defection they begin to contribute 0 points until the end of a given supergame.